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I/M FAILURE RATES BY VEHICLE MODEL

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Abstract

Previous analysis of vehicle emissions measured by roadside infrared sensors in Califonia indicates that vehicle emissions vary greatly by vehicle model. This analysis compares vehicle emission data by model year and model from two additional states using different measurement techniques to determine if differences in failure rates by vehicle model are consistent. Particular attention is paid to Arizona IM240 test results on relatively new (2- to 5-years old) passenger car models.

Previous Results from CA RSD Data

In a previous study we examined in-use emissions data on large numbers of vehicles from remote sensing measurements taken in California (Ross et al 1995; Wenzel and Ross 1996a, 1996b). The California Air Resources Board’s database includes 90,000 remote sensing measurements of about 60,000 vehicles, taken at several California sites in 1991. We took two steps to ensure that the remote sensing data were giving an accurate picture of in-use emissions, and were not measuring emissions during enrichment events. First, we only considered readings from sites where very few acceleration events were observed. Second, where possible, we averaged multiple readings of the same vehicle.

Figure 1 shows the failure rate (defined as exceeding 1% CO concentration) against the average CO concentration, for all cars of a given MY-model combination from MY87-89. In the figure, each point represents a particular MY-model combination (for example, 1987 Nissan Sentras). CO concentration for a model correlates well with the failure rate of that model. This is because just a few high emitters in a particular model will cause a noticeable shift in the mean for that model. There also is a wide range in failure rate, from no failures to nearly 30 percent failures, depending on the particular model. Remember that these vehicles are 2- to 5-years old, within the manufacturer’s warranty period for emission control components. Cars from five relatively inexpensive models of Asian manufacture (open circles) have an average failure rate of 17 percent. The average failure rate of the remaining models is 4 percent. Models from the 3 major Asian manufacturers appear in both groups. For example, 3 model years of Nissan Sentras, which is the least expensive Nissan analyzed, are among the highest emitters, while 3 model years of Nissan Maximas are among the lowest emitters. Most of the cars from these five models are carbureted, although some fuel-injected models are among the worst, and some carbureted models are among the best.

Comparison of Data From Three States

We next compared the California remote sensing data with I/M data from two states; we obtained one year of idle test data from Minnesota and eleven months of IM240 test data from Arizona. Table 1 compares the three types of emission tests. While the California and Minnesota data were collected in the same year, the IM240 data are from 1995: therefore cars of any given model year are 4 years older in the IM240 data. Idle and IM240 testing is more detailed than the RSD measurements: all three pollutants are measured, and testing is conducted over several minutes rather than one second.

However, there are limitations to all three types of data: the vehicle is not tested under load in the idle test, and vehicles are tested over different durations in the IM240 test. It also appears that inconsistent preconditioning is a problem with the IM240 data. For the most part, we study actual failure rates from the IM240 data, based on the interim cutpoints, to eliminate any bias from unequal testing durations and inconsistent preconditioning.

Table 1: Characteristics of Datasets from Three States

	RSD (California)	Idle (Minnesota)	IM240 (Arizona)
Test Year	1991	1991	1995
MY87-89 Vehicles:			
Number of Tests	15,000	409,000	180,000
Time Period	2 months	12 months	11 months
Vehicle Age	2 - 5 years	2 - 5 years	6 - 9 years
Pollutants	CO, HC	CO, HC, NOx	CO, HC, NOx
Cutpoints Used	CO: 1%	CO: 1%	CO: 30, 15 gpm HC: 2.0, 0.8 gpm NOx: 3.0, 2.0 gpm
Limitations	enrichment? cold starts? 1-sec. snapshot	vehicle not under load	different test duration; inconsistent pre-conditioning

Figure 2 shows CO failure rates of the MY87-89 models based on remote sensing and IM240 testing. The open circles are the five worst models identified by remote sensing. The range in failure rates is lower under the IM240 test, even though these vehicles are 4 years older than in the remote sensing data. This is most likely a result of the different types of tests and cutpoints used. The relationship between failure rate and car model appears relatively strong even as these models age.

Figure 3 plots the CO failure rates of the same models, as measured by remote sensing and idle testing. The idle test results in very low failure rates for these models, even when the same cutpoint (1%) is used. In addition, there is little agreement between the remote sensing results and the idle results; models with high failure rates under remote sensing and IM240 tests do not fail the idle test at the same rate. Perhaps this is not surprising, in that remote sensing and IM240 tests measure emissions under varying loaded operating conditions, whereas the idle test does not.

Table 2 shows the failure rates from each type of test, for the five worst models identified by remote sensing. Three of these models have high failure rates under both remote sensing and IM240 testing, particularly when final IM240 cutpoints are used. However, the other two models appear to be relatively clean based on the IM240 results.

The IM240 data identified several additional MY87-89 domestic models that have high failure rates, as shown in Table 3. We did not find these models in our analysis of the California remote sensing data because there are relatively few of them in California. These domestic models also may have had relatively high failure rates when they were 2- to 5-years old.

Results from AZ IM240 Program

We next calculated failure rates for 200 MY91-93 car models for which at least 100 cars were tested Figures 4 through 6 show the actual failure rate, based on Arizona's interim cutpoints (on the x axis) and the implied failure rate based on final cutpoints (on the y axis). The dashed line shows one-to-one correlation between failure rates under the two cutpoints. As expected, the implied failure rate, based on final cutpoints, would be higher than the actual failure rate. The implied final failure rates also correlate well with the actual failure rates.

Table 2. I/M Failure Rates for Five Worst Models as Identified by Remote Sensing

				CARB RSD		AZ IM240		
				all	road sites	start-up	final	MN Idle
MY	Man.	Model	Fuel	>1%	>1%	>30 gpm	>15 gpm	>1%
RSD and IM240 results agree for these 3 foreign models:								
1987	Foreign	A	Carb	30%	26%	17%	26%	10%
1988			Carb	27%	20%	14%	21%	2%
1989			Carb	28%	20%	9%	13%	1%
1987	Foreign	B	Both	27%	20%	11%	15%	1%
1988			FI	23%	14%	6%	12%	4%
1989			FI	22%	16%	4%	15%	0%
1987	Foreign	C	Carb	22%	8%	8%	17%	5%
1988			Carb	14%	14%	4%	8%	2%
1989			Carb	15%	9%	4%	7%	1%
... but not for these 2 foreign models:								
1987	Foreign	D	Carb	9%	4%	1%	4%	1%
1988			FI	13%	10%	1%	2%	1%
1989			FI	28%	26%	0%	2%	2%
1987	Foreign	E	Carb	18%	11%	6%	10%	1%
1988			Carb	18%	18%	2%	6%	0%
1989			Carb	15%	16%	1%	3%	2%
All Other Models				6%	4%	1%	3%	1%

Table 3. I/M Failure Rates of Models not Identified by California Remote Sensing

				CARB RSD		AZ IM240		
				all sites	road sites	start-up	final	MN Idle
MY	Man.	Model	Fuel	>1%	>1%	>30 gpm	>15 gpm	>1%
Domestic models identified by IM240								
1987	Domestic	A	EFI	13%	13%	14%	17%	8%
1988			EFI			7%	10%	4%
1989			EFI			1%	2%	3%
1987	Domestic	B				14%	24%	7%
1987	Domestic	C	Carb			20%	23%	16%
1988			Carb			13%	14%	18%
1989			Carb			5%	6%	11%
1987	Domestic	D	Carb			13%	17%	0%
1987	Domestic	E	Carb			14%	19%	2%
1988			Carb			9%	13%	2%
1989			Carb			7%	11%	0%
1987	Domestic	F	Carb			22%	44%	6%
1988			Carb			16%	9%	5%
All Other Models						2%	4%	2%

Again, we found that a few models (indicated by open circles) have failure rates several times that of all other models. We found 6 models with a combined CO failure rate of 5 percent (9 percent using the final cutpoints), 10 models with a combined HC failure rate of 5 percent (14 percent using final cutpoints), and 7 models with a combined NOx failure rate of 10 percent (14 percent using final cutpoints). Some models had high failure rates for more than one pollutant, but none were among the highest emitters for all three pollutants. Most of these high emitting models are of domestic manufacture, although not all three years of each model were among the worst emitters. The MY92 Saturn 1.9L engine with port fuel-injection failed both EPA and CARB in use compliance testing for HC emissions; this model has the third highest HC failure rate in Figure 8 (about 15%). However, the 1991 version of this model has an even higher failure rate under the Arizona IM240 program. The MY91 Saturn passed compliance testing at both EPA and CARB.

Next we looked at interim and final failure rates by mileage groups for the two worst MY91-93 models, as shown in Table 4. For most MY-models, failure rates are low at low mileage, and may increase at higher mileages. However, for in some model years for each of these models, failure rates are high, even under 50,000 miles when the vehicle is still under warranty (shaded boxes). For example, over 20% of MY91 Model B passenger cars with less than 50,000 miles fail for NOx in the Arizona IM240 program.

Table 4: Selected Passenger Car Model Failure Rates by MY and Mileage, 1995 Arizona IM240

			CO		HC		NOx	
			Start-Up	Final	Start-Up	Final	Start-Up	Final
MY-Model	Miles	Count	>20 gpm	>15 gpm	>1.2 gpm	>0.8 gpm	>2.5 gpm	>2 gpm
MY91 A	<25K	221	***6%***	***9%***	***6%***	***16%***	1%	2%
	25-50K	730	***6%***	***15%***	***7%***	***21%***	0%	1%
	50-75K	781	***10%***	***18%***	***9%***	***26%***	1%	2%
	>75K	395	***12%***	***22%***	***15%***	***31%***	1%	3%
MY92 A	<25K	358	2%	4%	***1%***	***8%***	0%	1%
	25-50K	1010	4%	8%	***4%***	***13%***	1%	1%
	50-75K	628	4%	11%	***5%***	***18%***	0%	0%
	>75K	169	8%	12%	***8%***	***22%***	0%	2%
MY93 A	<25K	603	4%	8%	***2%***	***10%***	0%	0%
	25-50K	1221	4%	8%	***1%***	***8%***	0%	0%
	50-75K	215	3%	7%	***4%***	***13%***	0%	0%
	>75K	82	4%	10%	***2%***	***15%***	0%	0%
MY91 B	<25K	96	0%	0%	***1%***	***13%***	***20%***	***30%***
	25-50K	275	0%	0%	***1%***	***12%***	***25%***	***37%***
	50-75K	228	1%	1%	***3%***	***22%***	***40%***	***49%***
	>75K	95	2%	2%	***12%***	***27%***	***44%***	***57%***
MY92 B	<25K	130	0%	0%	0%	2%	2%	3%
	25-50K	388	0%	0%	0%	1%	1%	3%
	50-75K	154	0%	0%	0%	2%	6%	10%
	>75K	37	0%	0%	3%	14%	11%	19%
MY93 B	<25K	305	0%	0%	0%	0%	0%	0%
	25-50K	363	0%	0%	0%	0%	0%	0%
	50-75K	73	0%	0%	0%	1%	0%	0%
	>75K	12	0%	0%	0%	0%	0%	0%

We also looked at MY91-93 light duty trucks. Figure 7 plots NOx interim and final failure rates for trucks. Again, there appears to be a wide range in failure rate by vehicle model. The model with the highest failure rate is the MY92 GM truck engine family that recently failed CARB in-use compliance testing for NOx. However, the other two years of this engine also are high NOx emitters, as are some other models.

Table 5 shows interim and final NOx failure rates by mileage for the two worst MY91-93 models. Again, failure rates tend to increase with mileage for some years. However, NOx failure rates are consistently high for all three years of Model A and two years of Model B (shown in bold italics). Model A is the engine family that failed recall testing; its recall for repair is being challenged by GM.

Table 5: Selected Light-Duty Truck Model Failure Rates by MY and Mileage, 1995 Arizona IM240

			CO		HC		NOx	
			Interim	Final	Interim	Final	Interim	Final
MY-Model	Miles	Count	>60 gpm	>40 gpm	>2.4	>1.6 gpm	>3.0 gpm	>2.5
MY91 A	<25K	178	0%	3%	6%	12%	***15%***	***15%***
	25-50K	490	0%	2%	2%	7%	***8%***	***10%***
	50-75K	767	1%	2%	3%	9%	***12%***	***13%***
	>75K	611	0%	3%	4%	13%	***14%***	***16%***
MY92 A	<25K	174	0%	0%	2%	7%	***20%***	***21%***
	25-50K	688	0%	0%	3%	9%	***24%***	***26%***
	50-75K	501	0%	0%	2%	8%	***30%***	***31%***
	>75K	220	1%	1%	5%	11%	***36%***	***39%***
MY93 A	<25K	333	0%	0%	1%	3%	***14%***	***17%***
	25-50K	669	0%	0%	1%	4%	***20%***	***23%***
	50-75K	225	0%	1%	1%	4%	***23%***	***24%***
	>75K	71	0%	0%	1%	4%	***31%***	***37%***
MY91 B	<25K	39	0%	0%	3%	8%	***3%***	***10%***
	25-50K	132	0%	0%	2%	4%	***9%***	***11%***
	50-75K	219	0%	0%	1%	7%	***13%***	***15%***
	>75K	121	0%	0%	6%	13%	***20%***	***22%***
MY92 B	<25K	59	2%	2%	3%	7%	***14%***	***17%***
	25-50K	153	0%	0%	0%	5%	***10%***	***12%***
	50-75K	90	1%	1%	1%	7%	***19%***	***21%***
	>75K	27	0%	0%	7%	7%	***22%***	***22%***
MY93 B	<25K	88	0%	0%	0%	0%	7%	8%
	25-50K	166	1%	1%	1%	3%	4%	8%
	50-75K	34	0%	0%	0%	3%	3%	9%
	>75K	14	0%	0%	0%	7%	21%	21%

Failure Rate by Station

Finally, we looked at failure rates by test station to determine if aggregate driver differences affect failure rates. We focused on two stations that represent the extremes in average driver income: Station 4, which is in a relatively low-income area, and Station 10, in a relatively high-income area.

Figure 8 shows the average HC failure rate for cars by model year and by test station. Cars tested at Station 4 have significantly higher, and cars tested at Station 10 significantly lower, failure rates than cars tested at all other stations. We suspect this large difference is due to the income differences between the two areas, which may result in inadequate vehicle maintenance in the less affluent neighborhood. (The increase in failure rates in MY91 cars is due to stricter cutpoints applied to MY91 and newer cars).

We next examined model-specific failure rates for MY91-93 cars at each test station. We only considered those models that had at least 100 cars in the entire dataset, and at least 20 cars at each of the two test stations. Figure 9 ranks the 71 models by increasing overall HC failure rate (diamonds). The circles are paired failure rates of each model at the two test stations (closed circles are from Station 4, open circles from Station 10). Models that have no circles had no failures at both test stations. Over half of these MY91-93 models are consistently clean at each station. However, for virtually every other model, the failure rate is higher at Station 4 than at Station 10. Many of the models failing at Station 4 show no failures at Station 10. This finding is even more striking when we look at average HC results by model and test station. These plots suggest that I/M failure rates for modern, 2- to 5-year old cars are sensitive to how individual drivers treat their cars. These plots also indicate that manufacturers can design cars that have essentially no failures within 5 years.

Uses of Failure Rates by Model

We believe that careful analysis of state I/M data can be used for several purposes. First, a list of vehicle models and their failure rates can be published, to give consumers information on the likelihood that their car will fail an I/M test in the future. Published rankings of failure rates by model will also make the relative emission levels of models more prominent, and may spur manufacturers to improve the effectiveness and durability of their emissions control systems.

Second, failure rates by model could be used to target specific engine families for further, more detailed in-use compliance testing under existing EPA and CARB programs. These programs have limited effectiveness in that only a few engine families, and that only a few (10 to 15) vehicles of each of these families, are tested each year. State I/M data from hundreds of thousands of vehicles can identify engine families that are suspected high emitters, and agency resources can be targeted towards testing a truly representative sample of those engines.

Third, the data can be used to evaluate the effectiveness of different I/M programs in different states. If a model with known high failure rates is frequently passed in a particular state, this is an indication that there is a problem in that state's I/M program.

Finally, at the state level, failure rates by vehicle model can be used to identify potential high emitters for more detailed I/M testing, such as the High Emitter Profile California is proposing. Or they can be used to identify potential low emitters to be waived from I/M requirements, as Arizona is considering.

Summary

Our analysis indicates that failure rates and average emissions by vehicle model from idle I/M test data do not correlate with remote sensing measurements or IM240 test results. IM240 data support earlier results for for MY87-89 cars using remote sensing measurements: a few models have failure rates several times that of all other cars; differences in failure rate by model continue as vehicles age, up to 9 years; and IM240 data indicate that a few domestic models may also have been among the worst CO emitters of MY87-89 cars. The IM240 data show similar results for MY91-93 car models. In addition, many models with high average CO emissions also have high average HC emissions, while many models have high HC and NOx emissions. In contrast with our earlier finding, most of the worst MY91-93 models are of domestic manufacture. For most car models, average emissions tend to increase with increasing mileage; however, some models have high average emissions under 50,000 miles. The IM240 data also correctly identify certain engine families that have been recalled under EPA and CARB In-Use Compliance testing programs. Finally, our analysis of emissions by vehicle model and I/M test station suggests that poor vehicle maintenance affects emissions and failure rates, even for new, modern technology cars; however, most modern car models do not appear to be sensitive to poor maintenance

Figure 1. CO Failure Rate and Average Concentration
MY87-89 Car Models, 1991 California Remote Sensing

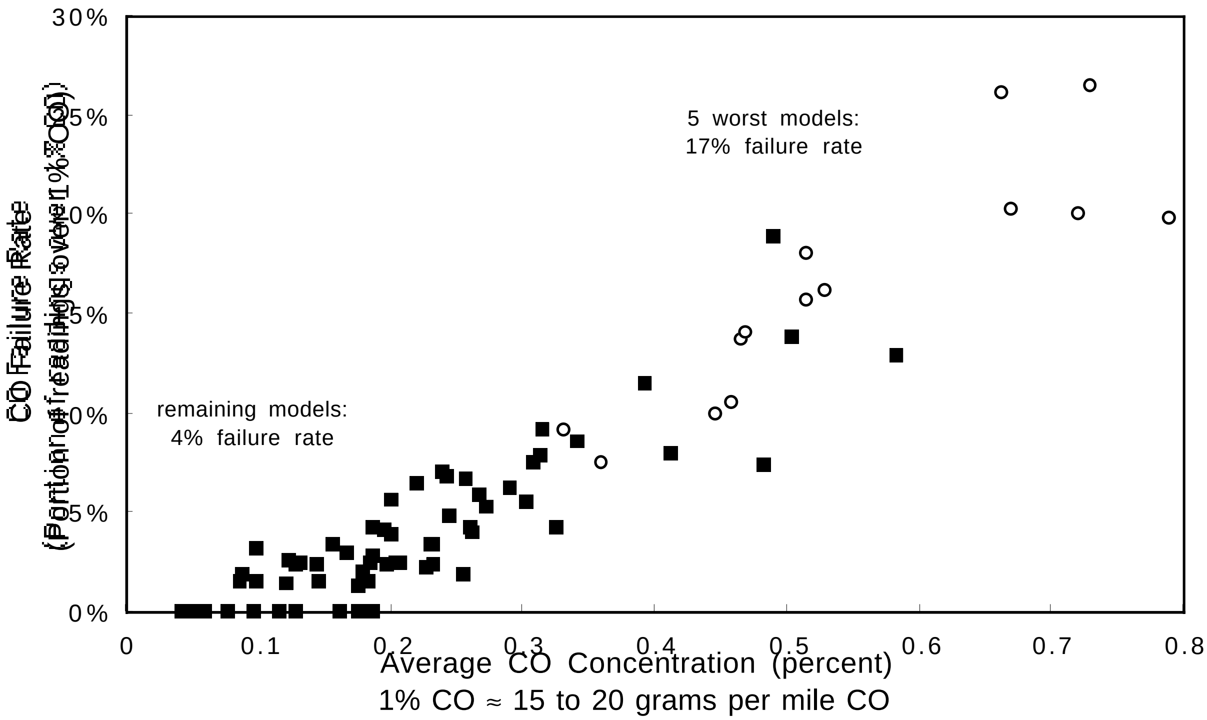


Figure 2. CA RSD and AZ IM240 CO Failure Rates by Model
MY87-89 Models

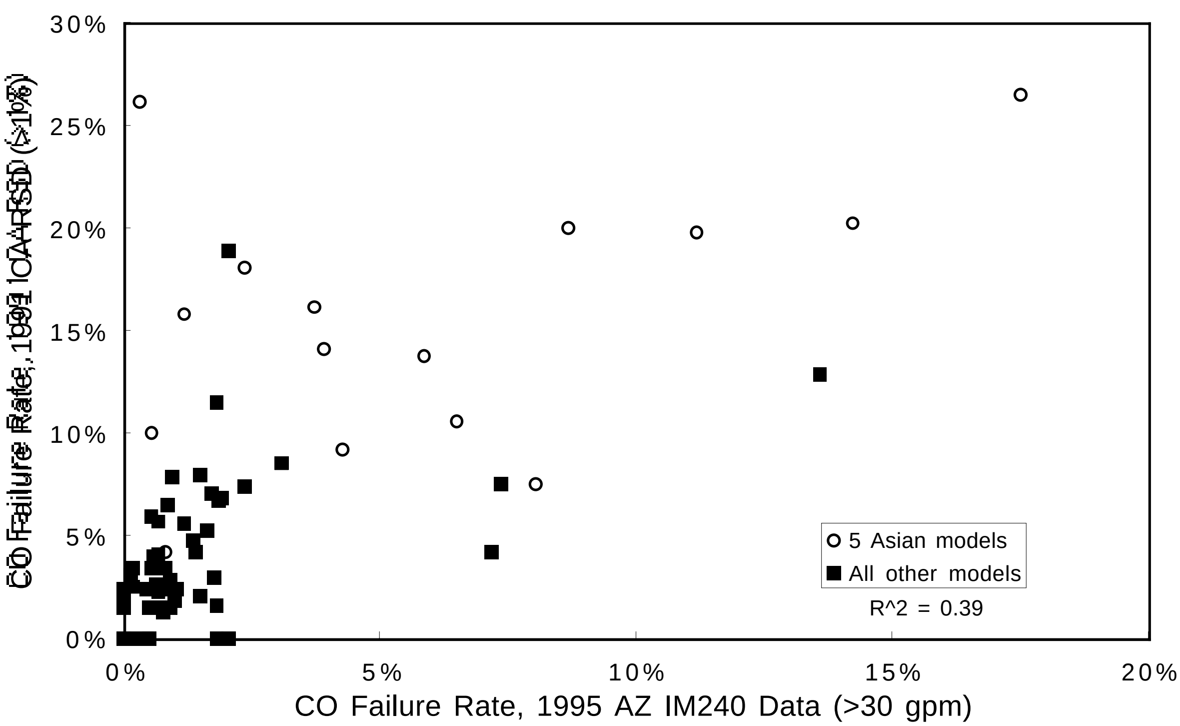


Figure 3. CA RSD and MN Idle CO Failure Rates by Model
MY87-89 Models

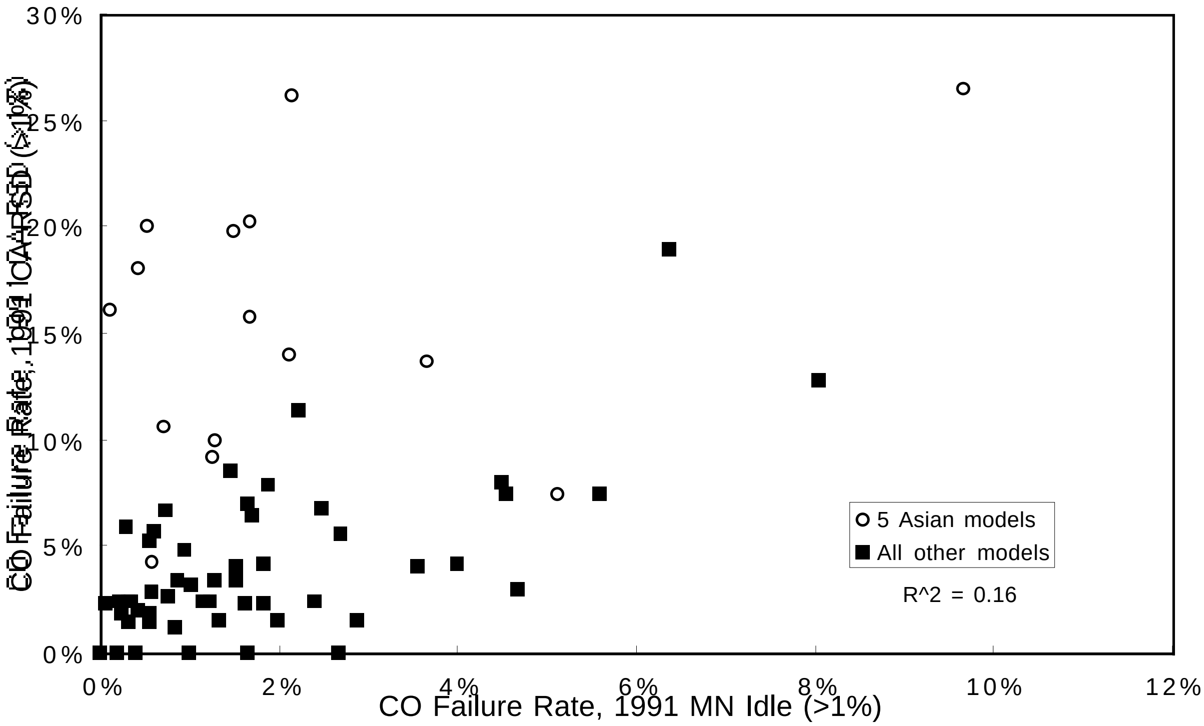


Figure 4. CO Failure Rates, MY91-93 Car Models
1995 AZ IM240 Data

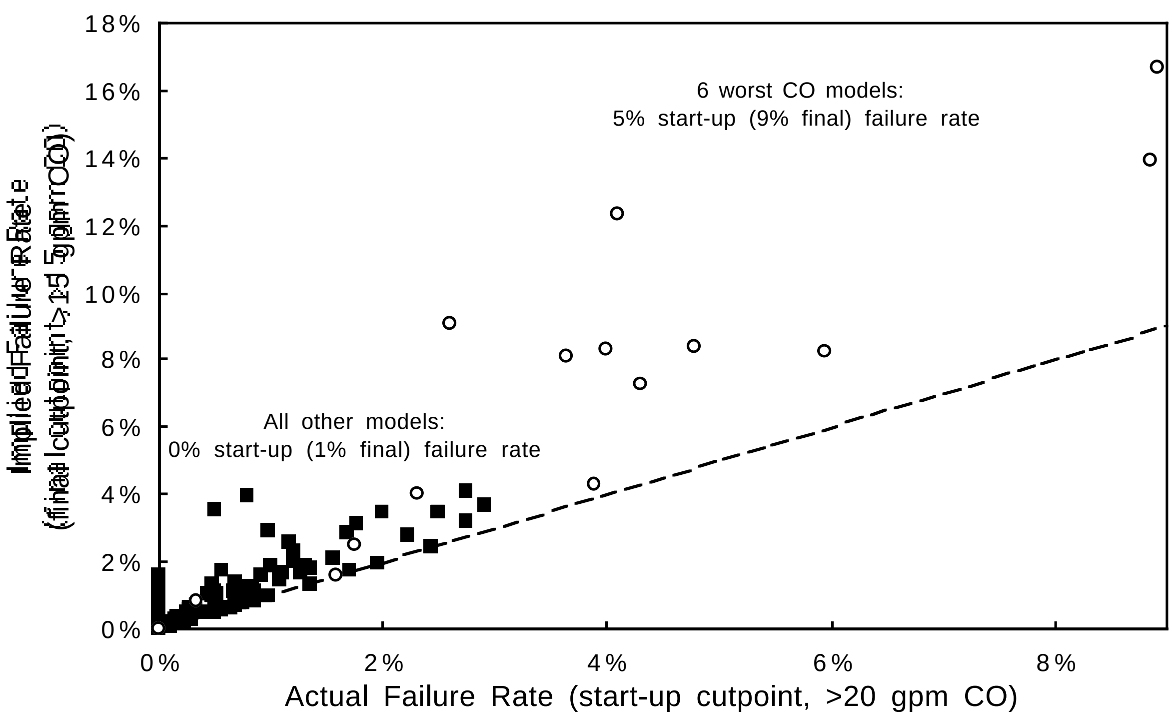


Figure 5. HC Failure Rates, MY91-93 Car Models
1995 AZ IM240 Data

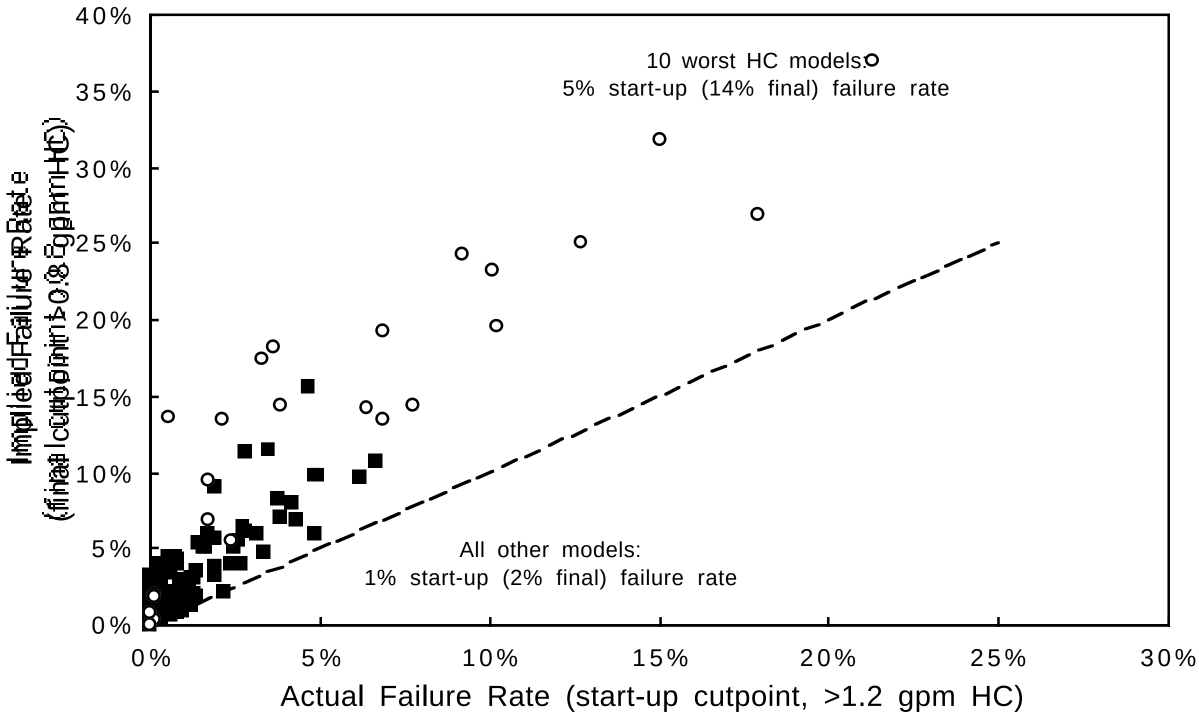


Figure 6. NOx Failure Rates, MY91-93 Car Models
1995 AZ IM240 Data

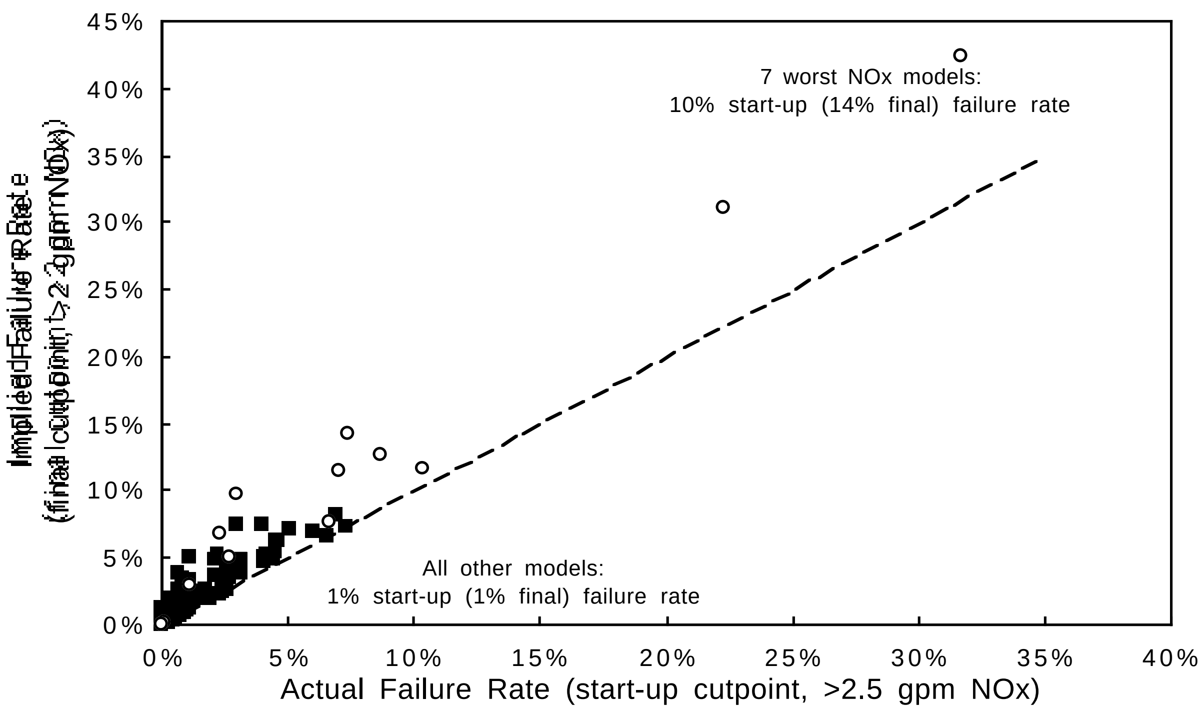


Figure 7. NOx Failure Rates, MY91-93 Light Truck Models

1995 AZ IM240 Data

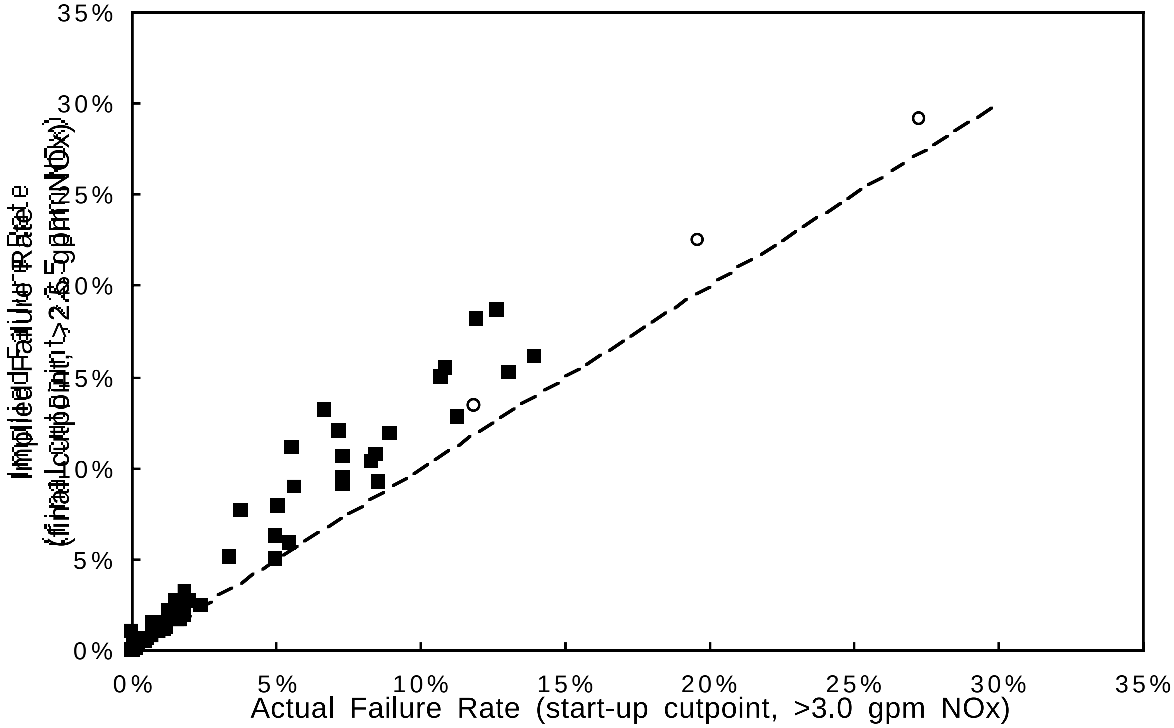


Figure 8. HC Failure Rates by MY and Test Station

1995 AZ IM240 Data

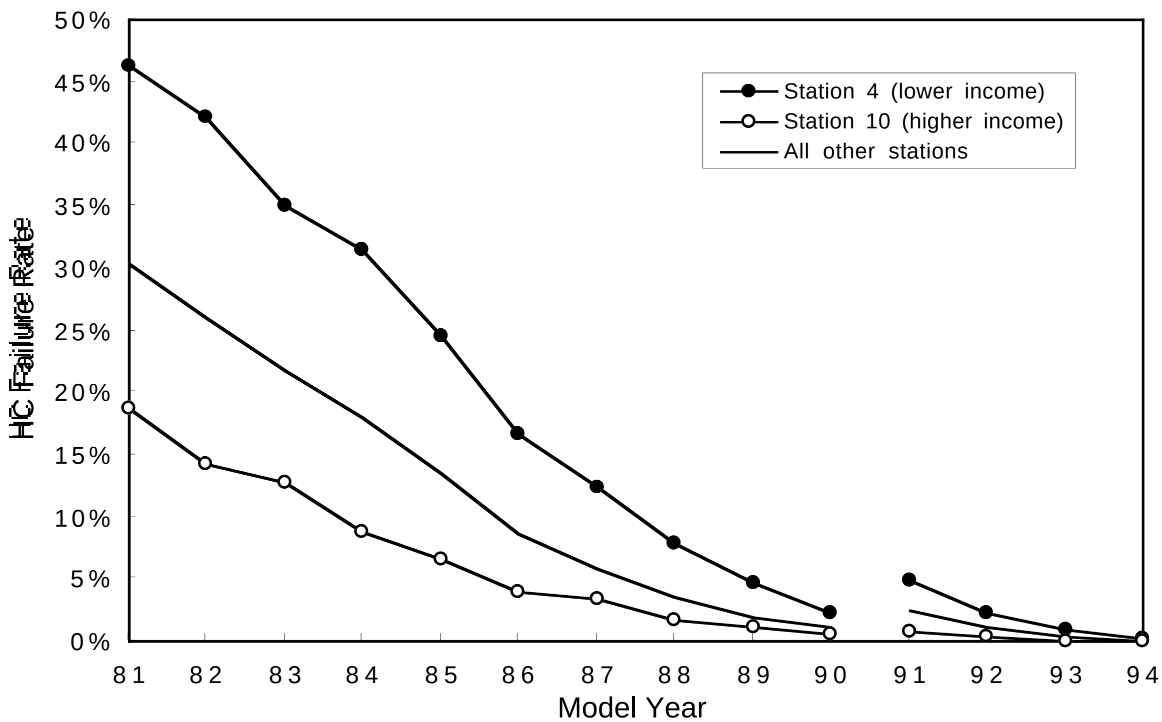


Figure 9. HC Failure Rate by Test Station, MY91-93 Car Models
1995 AZ IM240 Data

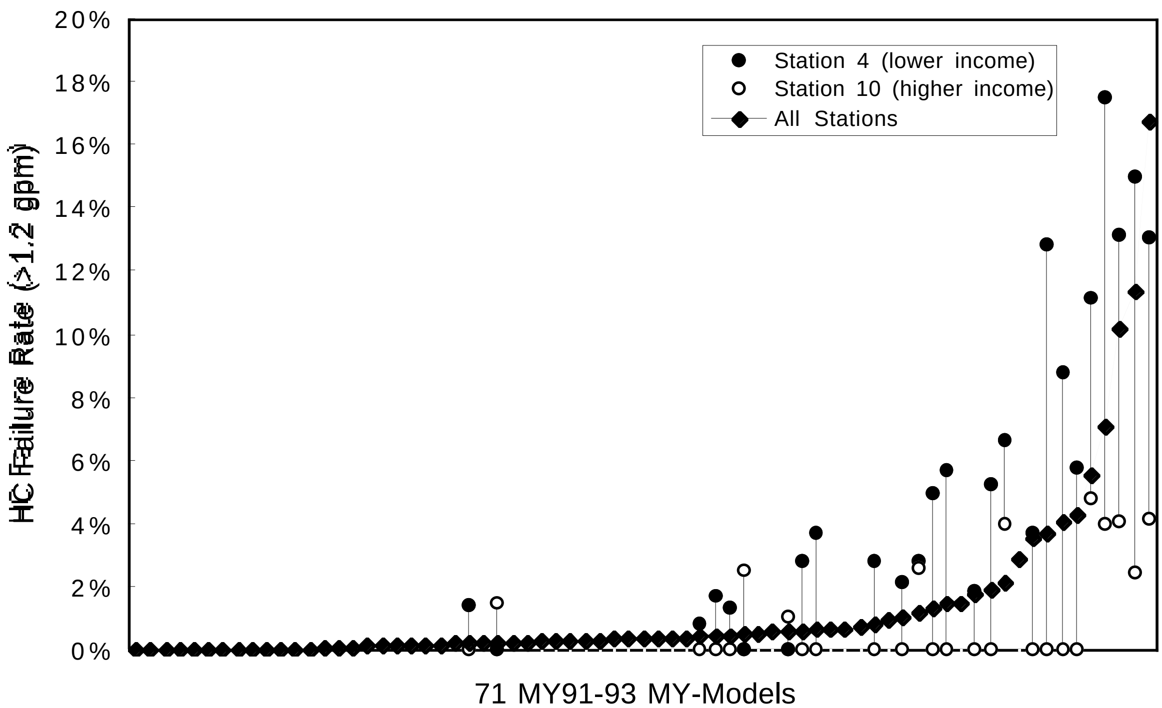
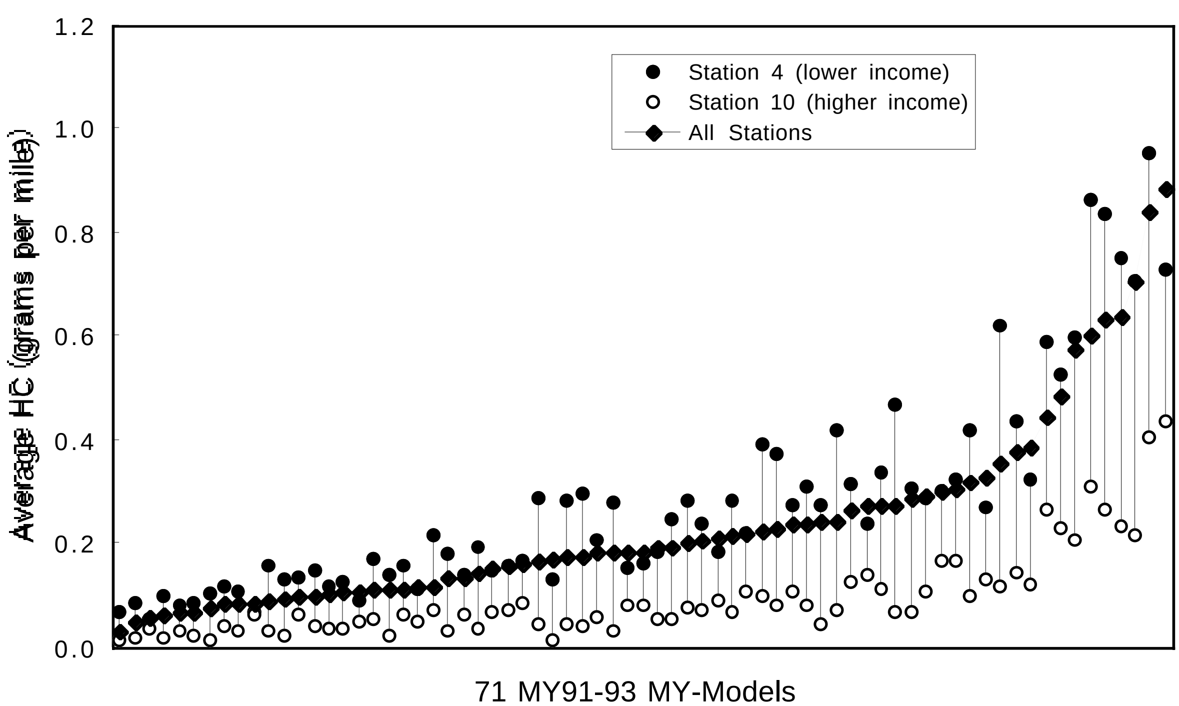


Figure 10. Average HC by Test Station, MY91-93 Car Models
1995 AZ IM240 Data



References

Ross, Marc, Rob Goodwin, Rick Watkins, Michael Q. Wang and Tom Wenzel. 1995. *Real-World Emissions from Model Year 1993, 2000, and 2010 Passenger Cars*. Lawrence Berkeley National Laboratory. LBL-37977. November.

Wenzel, Tom and Marc Ross. 1996a. *Emissions from Modern Passenger Cars with Malfunctioning Emissions Controls*. Society of Automotive Engineers Technical Paper Series. SAE 960067.

Wenzel, Tom and Marc Ross. 1996b. "Relationship between Vehicle Attributes and Malfunction of Emissions Control Systems." Proceedings of the Sixth CRC On-Road Vehicle Emissions Workshop. March.